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General Specifications—Appendix 8

INSTRUCTIONS FOR CALCULATING AND TESTING

Ventilation Systems

WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

INSTRUCTIONS FOR CALCULATING AND TESTING

Ventilation Systems.

DESIGNING SYSTEMS.

1. A series of experiments at the Experimental Model Basin, Washington, D. C., have been made for the purpose of obtaining information for designing ventilation systems for naval vessels.

2. The standard conditions which have been adopted for supply mains are a pressure of 5 pounds per square foot in the moving air at the inlet of the main or outlet of fan and a velocity of 2,000 feet per minute. The fan should be capable of maintaining this pressure aboard ship on discharge side, whatever the pressures on inlet side. This pressure of 5 pounds per square foot is for standard conditions of air, density at 70° F., and a relative humidity of 70 per cent. Under these standard conditions a cubic foot of air weighs .07465 pound. (See Table I.) The pressure of 5 pounds is equivalent to a pressure head of 67 feet of standard density air. A velocity of 2,000 feet per minute corresponds to a velocity head of 17.27 feet. The total head, then, against which air is delivered to the supply mains is 84.27 feet, which constitutes a very suitable combination of velocity and pressure head, giving a delivery close to the maximum possible for the total head.

3. As it is impossible to avoid loss of total head along the duct, due to friction, with resulting loss of delivery

264624

from the standard, it is necessary to make up the loss of delivery, and the following formulas may be used:

4. The formula for loss of head in a round or square pipe is $H_f = 4 f \frac{l}{d} V_1^2$ where H_f is loss of head in feet of air due to friction, f is the coefficient of friction, l and d are length and diameter of pipe, both expressed in feet or both in inches, and V_1 is the velocity of flow through the pipe in feet per second. If V_1 is changed to V or velocity in feet per minute and f given its proper value for first-class piping, namely, .00008, upon substituting and reducing $H_f = \frac{l}{d} \frac{V^2}{11250000}$. If $V = 2000$ $H_f = .3556 \frac{l}{d}$. If $V = 1000$ $H_f = .0889 \frac{l}{d}$.

5. Rectangular branches or mains should be avoided wherever practicable. Where such mains are used and are under standard conditions diagram (fig. 1) can be used for delivery. For loss of head the formula for a square main is the same as for a round main. For a rectangular pipe of short side h and long side nh, the formula to be used for loss of head is $H_f = \frac{l+n}{n} \frac{l}{h} \frac{V^2}{2250000}$ where l is length of pipe and V is velocity of air through it in feet per minute, h_f being loss of head in feet of air due to friction.

6. Using these formulas, knowing everywhere the size of a main and the discharge at each outlet, the head at each outlet, as compared with standard total head of 84.27 feet can be determined. Each foot of head lost means an approximate loss of about 0.6 of 1 per cent of delivery as compared with standard conditions. For instance, at an outlet where 364 feet per minute are needed, the total head is 69.27 feet, a loss from standard of 15 feet. The corresponding loss of delivery is 9 per cent and the actual

delivery to be expected will be only 91 per cent of the standard delivery. Then the standard delivery would be $\frac{364}{.91} = 400$ cubic feet per minute and if the outlet is made of the size corresponding to the diagram (fig. 1) to pass 400 cubic feet under standard conditions it will give the required 364 cubic feet under actual conditions.

7. The standard conditions in the main at the first outlet should be 5 pounds pressure, and 2,000 feet per minute velocity. As the branches lead off, do not change the size of the main until sufficient air has been removed to reduce the velocity to a value between 1,200 and 1,500 feet per minute, then contract the mains with a taper of 1½ inches to the foot until the area is so reduced that the velocity again becomes 2,000 feet per minute. Repeat the contraction wherever necessary, but do not reduce the final diameter of the main to less than twice the diameter of the last branch.

8. When laying out the branches make the angle anything less than 45°; 30° is a very good angle to use, but it is not necessary to adhere to it rigidly. For the branches at the extreme end of the main, where the velocity is very much reduced, the angle should be increased and the last branch should generally lead off at 90°.

9. When determining the length of branches, for one 90° elbow add 3 feet to the length of the branch; for two add 7 feet, and for three add 10 feet. For elbows less than 90° add in proportion. This applies to elbows the radius of which to the center of the pipe is 1½ diameters. A smaller radius should never be used.

10. From the layout of the system, the delivery required for each outlet and the length of branches corrected for elbows is known, then determine the size of inside diameter of the branch from the diagram. (Fig. 1.) For branches leading from the main where the head is materially below the standard, determine the proper enla delivery which should take place under standard cc tions as explained above, and from the diagram (fi determine the proper size of branches correspon The diameter of the branches should be to the ne ½ inch.

11. Each terminal is to be connected with its branc a cone expanding 1½ inches to the foot, making it su diameter that the air velocity at discharge will be required.

ASSEMBLING MANOMETERS.

12. To assemble the direct reading manometers (fi for measuring air velocity and pressure, place the t which is a double tank, in the supporting stand, and filling the inner tank with water to overflowing, leve means of the four screws in feet, fill outer tank to a d of about 4 or 5 inches with water. This water in c tank is to supply additional water necessary from to time to keep a constant water level in inner t that is, to keep it always just overflowing. This is by means of the small hand pump placed in one cc of the outer tank.

13. Next place the copper cans or floats, each of w is divided into 9 sections, inverted into the inner tank each section inclosing one of the 9 brass tubes stan up from the bottom of the inner tank. Then the beam with sliding weight to the right-hand side can be suspended by the two coil springs from above w are adjustable for height by small handwheel and sc The copper cans or floats can then be hooked to beam by hooks 4 inches long, and the circular scale then suspended in center from bottom of the knife-support.

14. When this much is assembled and all is perf free to move up and down with the motion of the spr

[illegible]

the larger weights [illegible]
pan box.

•

16. It [illegible]
[illegible]
assembled and the scale [illegible]
the weights on the pan [illegible]

rially below the standard, determine the proper enlarged delivery which should take place under standard conditions as explained above, and from the diagram (fig. 1) determine the proper size of branches corresponding. The diameter of the branches should be to the nearest ½ inch.

11. Each terminal is to be connected with its branch by a cone expanding 1½ inches to the foot, making it such a diameter that the air velocity at discharge will be that required.

ASSEMBLING MANOMETERS.

12. To assemble the direct reading manometers (fig. 2) for measuring air velocity and pressure, place the tank, which is a double tank, in the supporting stand, and after filling the inner tank with water to overflowing, level by means of the four screws in feet, fill outer tank to a depth of about 4 or 5 inches with water. This water in outer tank is to supply additional water necessary from time to time to keep a constant water level in inner tank; that is, to keep it always just overflowing. This is done by means of the small hand pump placed in one corner of the outer tank.

13. Next place the copper cans or floats, each of which is divided into 9 sections, inverted into the inner tank with each section inclosing one of the 9 brass tubes standing up from the bottom of the inner tank. Then the scale beam with sliding weight to the right-hand side can next be suspended by the two coil springs from above which are adjustable for height by small handwheel and screw. The copper cans or floats can then be hooked to scale beam by hooks 4 inches long, and the circular scale pan then suspended in center from bottom of the knife-edge support.

14. When this much is assembled and all is perfectly free to move up and down with the motion of the springs, the scale beam with its sliding weight on zero should then be leveled accurately by small level on right-hand side held by brass clips and by the adjustable counter weight on the left.

15. After all is level then place weights on scale pan and check for level again, always keeping water in inner tank to overflowing. The gear for calibrating the suspension springs consists of a 3 to 1 multiplying sheave, over which a small cord is led from the center of the knife-edge supports vertically through a sheave to the small sheave of the multiplying gear and after a few turns around the small sheave is well secured, another cord passing several times around the larger sheave and hanging vertically with weight attached for keeping tight. On this vertical cord a small aluminum pointer is fastened, back of which a paper scale is placed and fastened on a board. Place scale with its zero at top, and 3 inches from the bottom of the horizontal board upon which the multiplying sheaves are fastened. This scale is a diagonal scale, and can be shifted horizontally to right or left to accommodate any change in the springs that might occur. Brass weights weighing 1,995 grains and larger weights weighing 7,980 grains are provided with each instrument. These weights are for calibrating the suspension springs and checking points on the diagonal scale, and they are of such weight that the elongation produced by the smaller weights will be equal to a pressure of 1 pound per square foot over the area of the copper cans or floats. The larger weights represent a pressure of 4 pounds per square foot.

SCALE.

16. To establish then a scale by which can be read off the pounds per square foot pressure—after the instrument is assembled and the scale beam level—put enough of the brass weights on the pan to give the pressure desired in the particular experiment, and then adjust the small aluminum pointer on zero of the paper scale, then take off all weights, and the pointer should then come to the number on the paper scale corresponding to the number of pounds per square foot represented by the weights removed. If the pointer does not come to the proper line on the scale, shift same horizontally until it does, then place weights on again and check up zero. The hand wheel on the top of the instrument can be used when only a small change in the adjustment of the aluminum pointer is necessary.

17. The sliding weight, 4,488 grains, on the scale beam serves two purposes:

1. Its distance out on the beam as read on the scale on this beam represents the excess of pressure in pounds per square foot of the 9 "impact" tubes over the 9 "static" tubes of the Pitot tube sets.

2. With the Pitot tube the velocity of moving air can be determined when this excess pressure is known. Therefore the movement of the sliding weight necessary to balance the pressure of the "impact" and "static" tubes, when referred to a scale calculated with the proper coefficients, will give a reading of velocity in feet per minute. Such a scale is placed on two small rollers under the sliding weight, which has a pointer attached. Since the velocity will vary for various values of barometric pressure, temperature, and humidity of the atmosphere, the scale is also calculated for various values of $\sqrt{\frac{2g}{e}}$ or velocity coefficient ($g=32.16$; $e=$w't of air in lbs. per cu. ft.). See Table II.

18. To determine the scale to use, find from tables furnished the velocity coefficient for barometric pressure and temperature for the atmospheric condition and the time, rotate the sheet on the rollers until this velocity coefficient comes under the pointer; readings of velocity will then be correct for that atmospheric condition only.

19. Changes in the atmospheric condition must be followed up by a new determination of velocity coefficient and adjustment of the proper scale. The scales used are prints on paper or linen from a negative made from a tracing. The tracing when made was enlarged 1.75 per cent to allow for the double shrinkage in printing and this allowance would make the print for use correct if the same kind of paper were always obtainable, but as the shrinkage of paper is liable to vary, it is necessary to furnish dimensions in inches for one point on each scale, and the point for 4,000 feet per minute is taken.

20. Then measuring on lines of velocity coefficients tabulated the distance from zero to 4,000-foot point should be as follows:

Velocity coefficients.	Distance in inches to 4,000-foot point from zero.
30.4	9.618
30.2	9.746
30.0	9.876
29.8	10.010
29.6	10.146
29.4	10.284
29.2	10.425
29.0	10.570
28.8	10.717
28.6	10.867

21. When the distance out from zero *does not* agree with tabulated distances given in table for the various velocity coefficients, it is then necessary to *shift* the velocity-coefficient scale so as to make the 4,000-foot point the proper distance from zero.

circle one-ninth area of the pipe, tube No. 2 in the first ring from center, tube No. 3 in the second ring from center, and so on.

26. For rectangular pipes and various other shapes the leads will have to be determined for each individual case.

LOCATION OF SLOTS.

27. The exact location of the slot in the mains to be tested should be decided upon with a view to fulfilling the following conditions as far as may be practicable in each case, viz:

28. The point chosen should be for mains as near fan as possible in an accessible location with, preferably, no branches taken off of the main between slots and the fan. It should be as far removed as possible from bends and elbows, particularly no bends or elbows should occur immediately ahead (in the direction of the fan) of the slots. Test will be made whenever possible on the discharge side of the fan, but same can be made on the suction side. The slots are to be provided with suitable air-tight covers for closing same when not in use.

LOCATION OF MANOMETER.

29. The manometer should be placed near enough to the position selected for the Pitot tube sets to allow connection between the two to be made by means of rubber tubing furnished. This rubber tubing is about one-fourth inch inside diameter and is 12 feet long. The Pitot tube sets should be placed in position and secured so that each tube is parallel with the axis of the pipe, any leaks around where the holder enters the pipe should be stopped by means of heavy cardboard, or better still, by rubber steam packing. Now all 9 tubes leading from the "slots" or "static" openings of the Pitot tubes must be connected by 9 rubber tubes to the 9 brass tubes in the rear of the

manometer. Similarly the "impact" openings must be connected to the other 9 tubes.

30. The instrument is arranged to have all these tubes leading from "impact" openings connected to the tubes which are inclosed by the copper can or float on the right, facing the instrument.

31. When it is desired to measure the velocity of the air in the suction pipe leading to a fan, *invert* the diagonal scale at the back of the instrument; then with no weights on the scale pan, the aluminum pointer (17) should be adjusted carefully on zero of the diagonal scale, and the calibration of the springs checked by placing on weights as before. It is also necessary to *heighten* the brass tubes that stand up from the bottom of the tank; on instruments made prior to July, 1908, this can be done by using a short length of rubber tubing about 1½ inches to 2 inches placed on the end of each, care being taken that when the greatest suction to be measured comes on, these rubber tubes will still be clear of the sides and not interfere with the free up and down movement of the floats. The readings then taken with the instrument in the suction pipe will be *negative* pressure or suction and will require the minus (—) sign, except that the reading registered on the scale beam is still *positive* being the excess of pressure of the "impact" tubes over the "static" tubes.

32. The Pitot tubes are, of course, inserted in the suction pipe with the open end pointing to the incoming current of air, and connected to the manometer the same as when measuring velocity on the pressure side of a fan.

TESTING SYSTEMS.

33. In connection with testing the ventilation systems on shipboard, great care should be exercised in the examination of all piping to see if same is clear of all rubbish, etc., and that the dampers and cowls are properly set, also that all compartments, to which the system is connected, are kept open for a free passage of air during the test.

34. The tests will usually consist of measuring in each system the static and impact pressures and the corresponding deliveries, with all louvers open, for high speed, low speed, and for about three or four intermediate speeds. Then a check on them consisting of all the readings can be had by plotting a curve of deliveries on the revolutions per minute. The points of this curve should approximate a straight line passing through the origin, if all louvers have remained open throughout the tests. A curve of pressure on the revolutions per minute will also be of advantage in showing the consistency of the readings.

SHIPMENT OF TESTING SET.

35. When the ventilation systems on any vessel are ready for test, the Naval Constructor will advise the Bureau of the probable date of such tests, and a testing set (figs. 2, 3, 4, and 5) will be supplied for this purpose. The Bureau will also detail an expert to conduct the tests, if necessary.

In reply address the Chief of the Bureau of Construction and Repair,
and refer to No. { 6218-A. 124.
(13164-A. 8.)

NAVY DEPARTMENT,

BUREAU OF CONSTRUCTION AND REPAIR,

WASHINGTON, D. C., *January 29, 1910.*

GENERAL SPECIFICATIONS—APPENDIX 8.

SUPPLEMENT No. 1.

The following modification to the "Instructions for Calculating and Testing Ventilation Systems" is issued for information and guidance in connection with work covered by the above instructions.

The modified paragraph given below is to be substituted for paragraph 5 in the above instructions.

This supplement corrects the formula for loss of head in rectangular pipes due to friction, which, as printed in the volume of "Appendices 1 to 18" and in the pamphlet edition of Appendix 8, contains a typographical error.

MICHAEL D. SCHAEFER,
Acting Chief of Bureau.

SUPPLEMENT No. 1. APPENDIX 8.

5. Rectangular branches or mains should be avoided wherever practicable. Where such mains are used and are under standard conditions, diagram (Fig. 1) can be used for delivery. For loss of head the formula for a square main is the same as for a round main. For a rectangular pipe of short side h and long side nh, the formula to be used for loss of head is

$$H_f = \frac{(1+n)}{n}\frac{l}{h}\frac{V^2}{22{,}500{,}000}$$

where l is length of pipe and V is velocity of air through it in feet per minute, H_f being loss of head in feet of air due to friction.

In reply address the Chief of the Bureau of Construction and Repair and refer to No. 6218–A. 142 (13164–A. 8).

NAVY DEPARTMENT,
BUREAU OF CONSTRUCTION AND REPAIR,

WASHINGTON, D. C., *October 7, 1910.*

GENERAL SPECIFICATIONS; APPENDIX 8.

SUPPLEMENT NO. 2.

The following modifications to the "Instructions for Calculating and Testing Ventilation Systems" are issued for information and guidance in connection with the above instructions.

The paragraphs modified are 2, 10, 28, and 34.

R. M. WATT,
Chief Constructor, U. S. Navy, Chief of Bureau.

SUPPLEMENT NO. 2, APPENDIX 8. OCTOBER 7, 1910.

Paragraph 2. Modify the second sentence to read as follows:

The opening to the inlet piping from the outside air and the inlet piping itself should be so designed that the loss of head between the outside air and the fan will not prevent the fan maintaining the above specified static pressure in the discharge duct while delivering the required volume of air.

SUPPLEMENT No. 2, APPENDIX 8. OCTOBER 7, 1910.

Paragraph 10. Modify last sentence to read as follows:

The diameter of the branches should be required to the nearest one-fourth inch larger than the diameter computed in accordance with the foregoing.

SUPPLEMENT No. 2, APPENDIX 8. OCTOBER 7, 1910.

Paragraph 28. Modify the second sentence to read as follows:

It should be as far removed as possible from bends and elbows; particularly, no bends, elbows, or change in the shape and size of the pipe should occur immediately ahead (in the direction against the moving air) of the slots.

SUPPLEMENT No. 2, APPENDIX 8. OCTOBER 7, 1910.

Paragraph 34. Modify the first sentence to read as follows:

The tests will usually consist of measuring in each main duct and in branches to important compartments the static and impact pressures and the corresponding deliveries, with all louvers open, for maximum speed, minimum speed, and about three or four intermediate speeds.

……

Dr p			38			39			40	
Ad e b			2.7			2.7			2.7	
B	dition r wet b de- ssion.	Weight of saturated air.	Addition for wet bulb depression.		Weight of saturated air.	Addition for wet bulb depression.		Weight of saturated air.	Addition for wet bulb depression.	
		0.07573			0.07557			0.07541		
		.07600			.07584			.07567		
		.07627			.07610			.07594		
		.07653			.07637			.07620		
		.07680			.07663			.07647		
		.07706			.07690			.07674		
	2	.07733	1	2	.07717	1	2	.07700	1	2
	4	.07760	2	4	.07743	2	4	.07727	2	4
	6	.07786	3	6	.07770	3	6	.07753	3	6
	7	.07813	4	8	.07796	4	8	.07780	4	8
	9	.07840	5	9	.07823	5	10	.07806	5	10
	11	.07866	6	11	.07850	6	11	.07833	6	12
	13	.07893	7	13	.07876	7	13	.07859	7	14
	15	.07920	8	15	.07903	8	15	.07886	8	15
	17	.07946	9	17	.07929	9	17	.07913	9	17
	19	.07973	10	19	.07956	10	19	.07939	10	19
	21	.08000	11	21	.07983	11	21	.07966	11	21
	22	.08026	12	23	.08009	12	23	.07992	12	23
		.08053	13		.08036	13	25	.08019	13	25
		.08080	14		.08062	14		.08045	14	
		.08106	15		.08089	15		.08072	15	
		.08133			.08116			.08098		
		.08160			.08142			.08125		
		.08186			.08169			.08151		
		.08213			.08195			.08178		
		.08239			.08222			.08205		
De d	1.6			1.6				1.6		

	48			49			50		
	2.6			2.6			2.6		
dition wet b de- ssion.	Weight of saturated air.	Addition for wet bulb depression.		Weight of saturated air.	Addition for wet bulb depression.		Weight of saturated air.	Addition for wet bulb depression.	
	0.07413			0.07397			0.07381		
	.07439			.07423			.07408		
	.07465			.07449			.07434		
	.07491			.07475			.07460		
	.07518			.07502			.07486		
	.07544			.07528			.07512		
2	.07570	1	2	.07554	1	2	.07538	1	2
4	.07596	2	4	.07580	2	4	.07564	2	4
6	.07622	3	6	.07606	3	6	.07590	3	7
8	.07648	4	9	.07632	4	9	.07616	4	9
10	.07674	5	11	.07658	5	11	.07642	5	11
13	.07701	6	13	.07684	6	13	.07668	6	13
15	.07727	7	15	.07710	7	15	.07694	7	15
17	.07753	8	17	.07736	8	17	.07720	8	18
19	.07779	9	19	.07762	9	19	.07746	9	20
21	.07805	10	21	.07788	10	22	.07772	10	22
23	.07831	11	23	.07815	11	24	.07798	11	24
25	.07857	12	26	.07841	12	26	.07824	12	26
27	.07883	13	28	.07867	13	28	.07850	13	28
29	.07910	14	30	.07893	14	30	.07876	14	31
31	.07936	15	32	.07919	15	32	.07902	15	33
	.07962			.07945			.07928		
	.07988			.07971			.07954		
	.08014			.07997			.07980		
	.08040			.08023			.08006		
	.08066			.08049			.08032		
1.5			1.5				1.5		

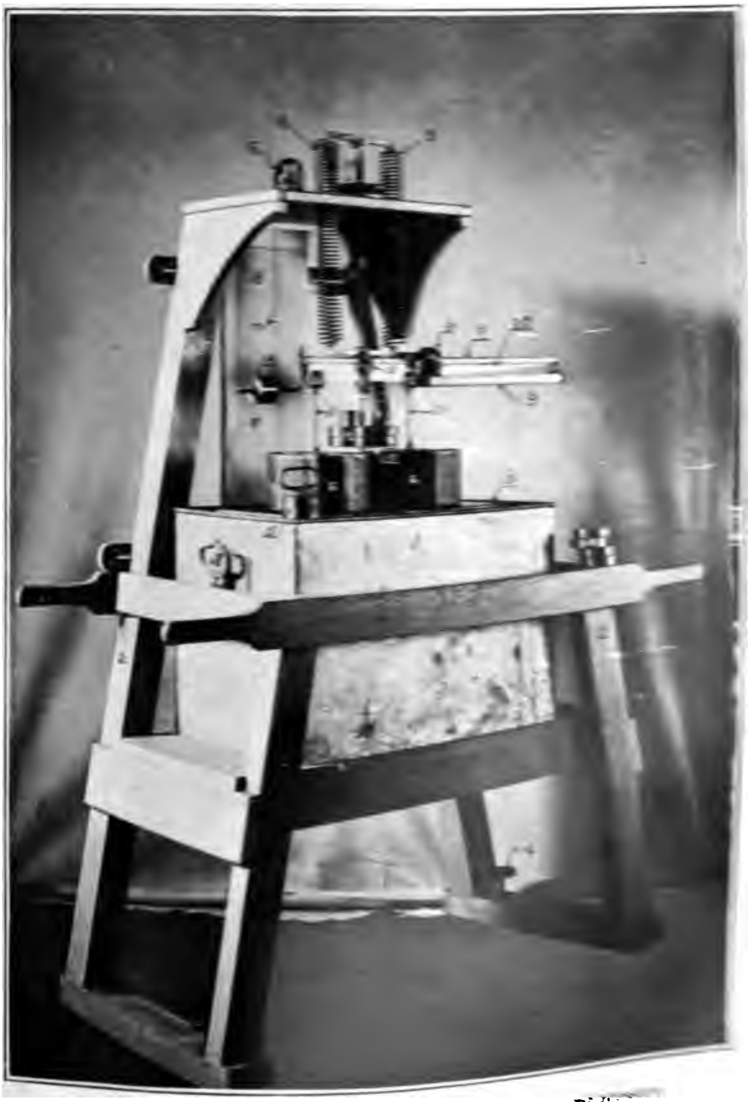

FIG. 2.—Direct reading manometer for measuring gas velocity and [illegible]

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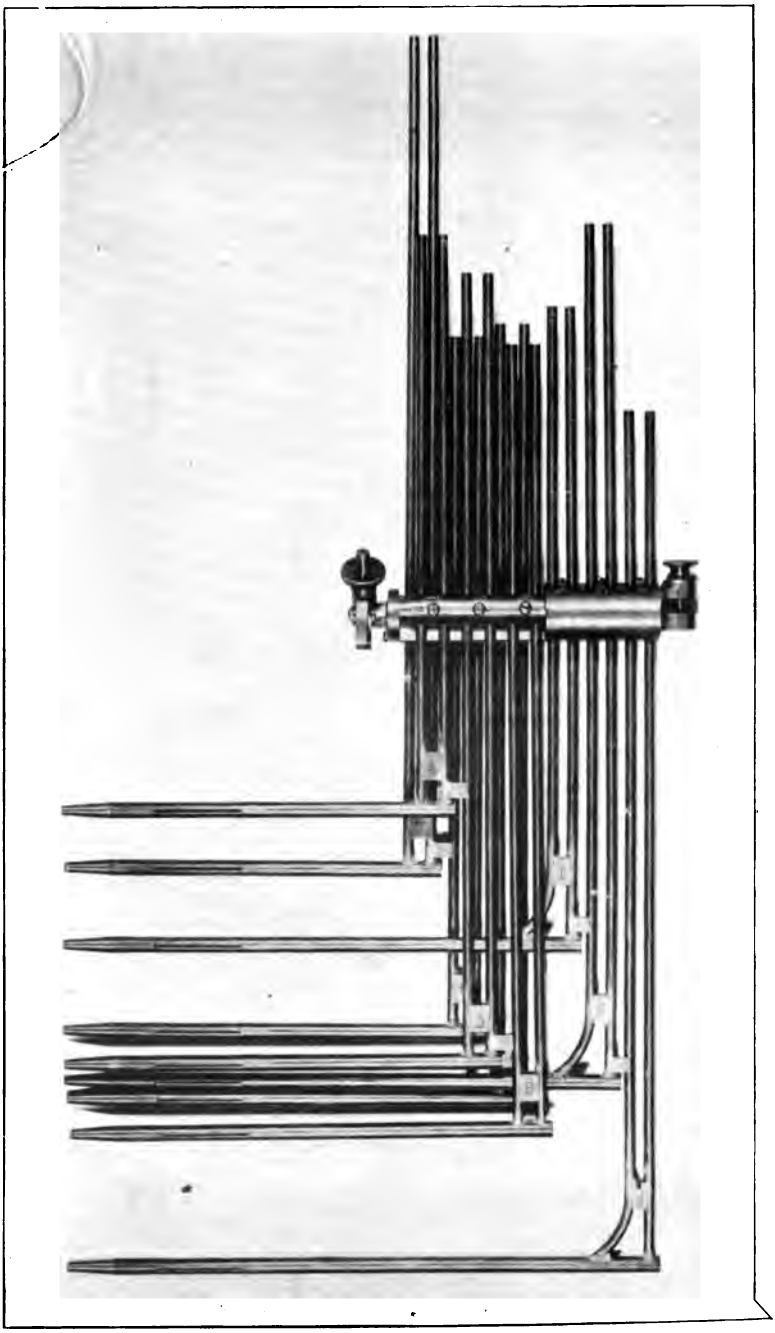
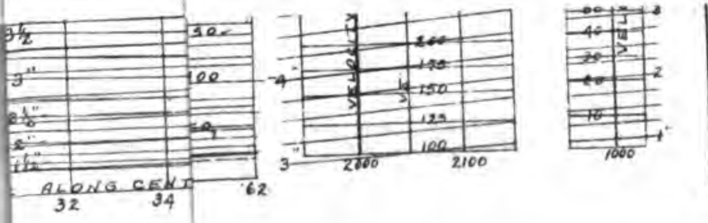


FIG. 3.—Adjustable pitot tube set.

Dry P		98			99			100		
B	ct for bulb ssion.	Velocity coefficient saturated air.	Deduct for wet bulb depression.		Velocity coefficient saturated air.	Deduct for wet bulb depression.		Velocity coefficient saturated air.	Deduct for wet bulb depression.	
		31.18			31.22			31.26		
		31.13			31.17			31.21		
		31.07			31.11			31.15		
		31.02			31.06			31.10		
		30.96			31.00			31.04		
		30.91			30.95			30.99		
	1	30.85	1	1	30.89	1	1	30.93	1	1
	2	30.80	2	2	30.84	2	2	30.88	2	2
	3	30.75	3	3	30.78	3	4	30.82	3	4
	5	30.69	4	5	30.73	4	5	30.77	4	5
	6	30.64	5	6	30.68	5	6	30.71	5	6
	7	30.58	6	7	30.62	6	7	30.66	6	7
	8	30.53	7	8	30.57	7	8	30.61	7	8
	9	30.48	8	9	30.52	8	9	30.56	8	10
	10	30.43	9	10	30.47	9	11	30.50	9	11
	11	30.38	10	12	30.41	10	12	30.45	10	12
	12	30.32	11	13	30.36	11	13	30.40	11	13
	14	30.27	12	14	30.31	12	14	30.35	12	15
	15	30.22	13	15	30.26	13	15	30.30	13	16
	16	30.17	14	16	30.21	14	17	30.25	14	17
	17	30.12	15	17	30.16	15	18	30.19	15	18
		30.07			30.11			30.14		
		30.02			30.06			30.09		
		29.97			30.01			30.04		
		29.92			29.96			29.99		
		29.87			29.91			29.94		


3½
3"
2½"
2"
1½"
ALONG CENT
32
34
50
100
50
.62
4"
3"
VELOCITY
200
175
150
125
100
2000
2100
60
40
30
20
10
VEL
1000
3
2
1"

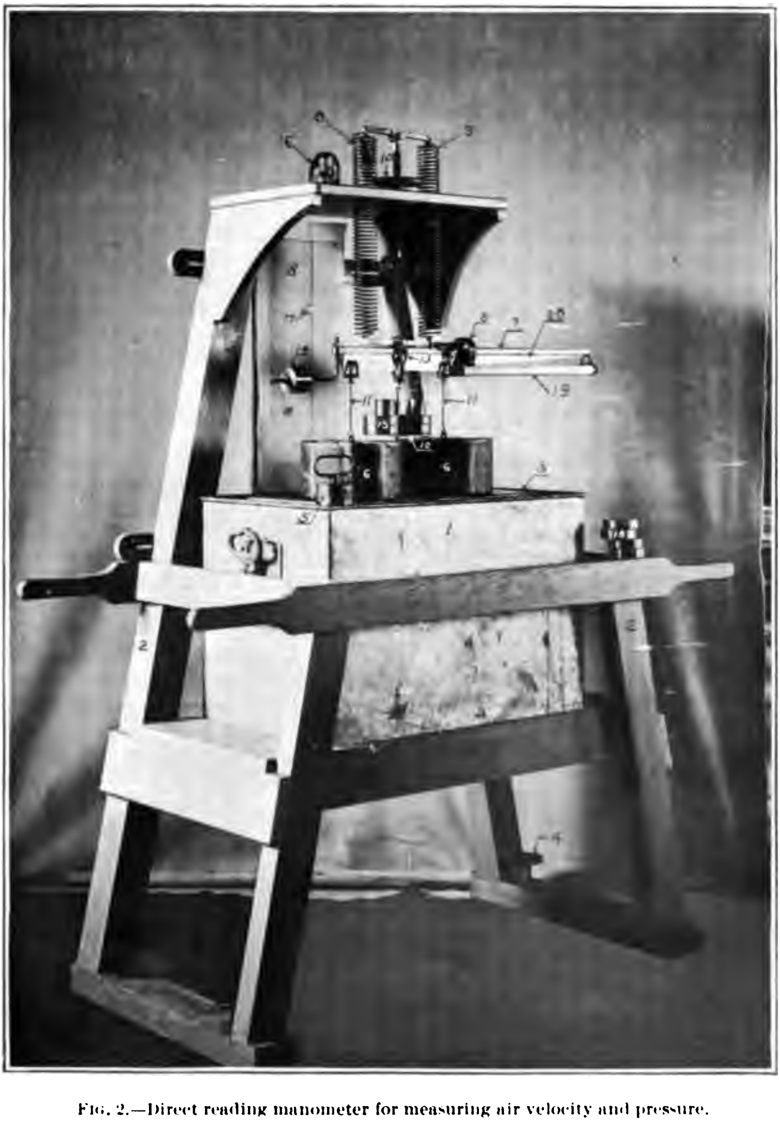


Fig. 2.—Direct reading manometer for measuring air velocity and pressure.

[illegible]

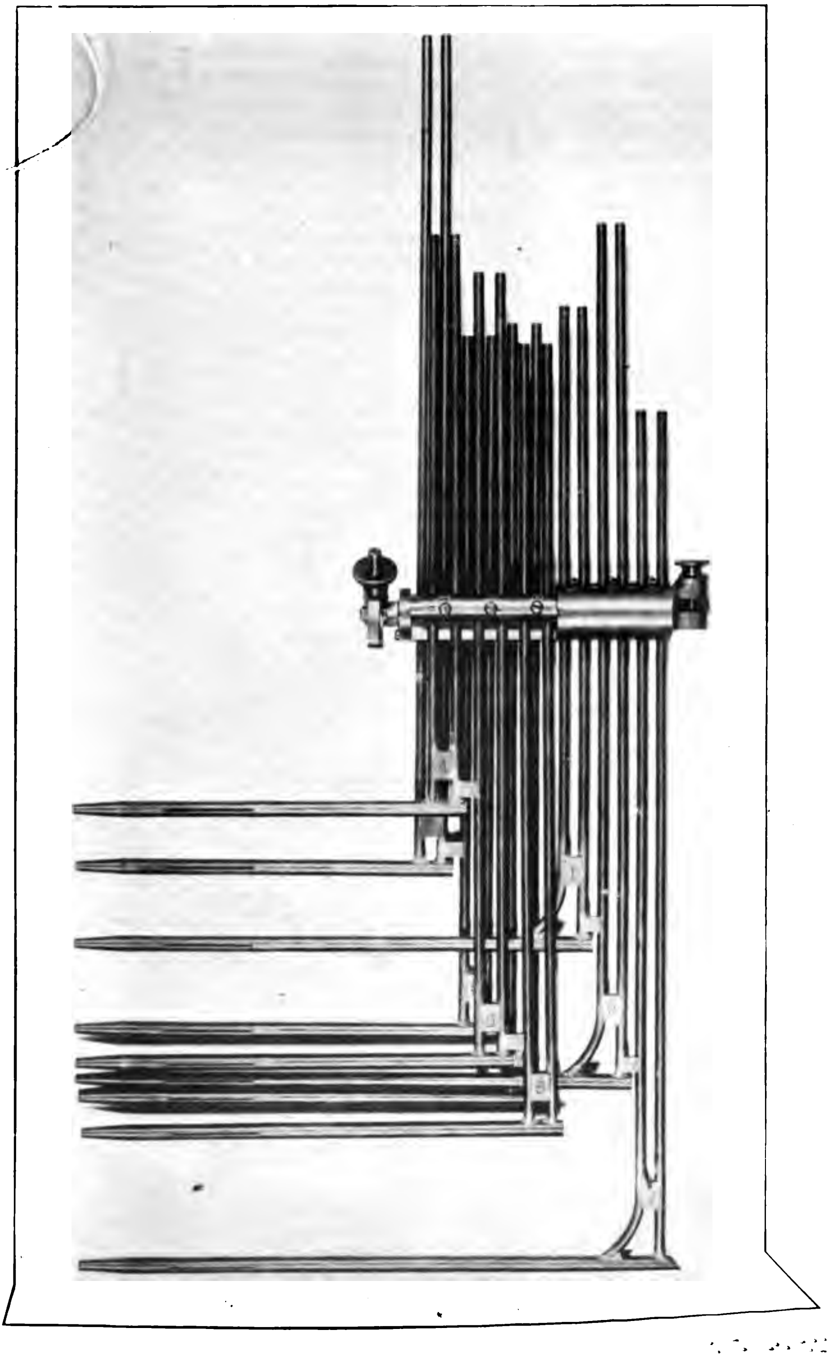


FIG. 3.—Adjustable pitot tube set.

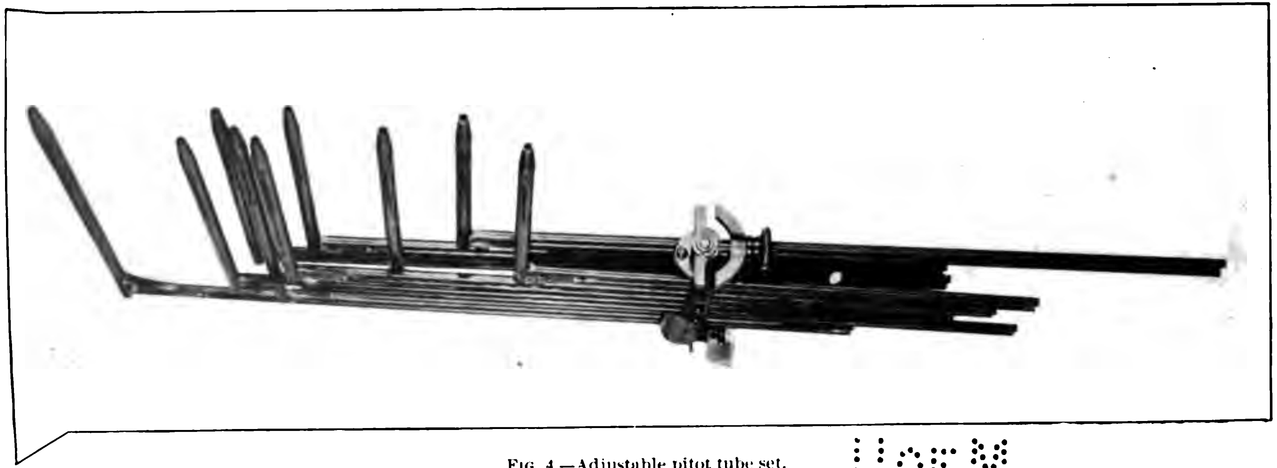


Fig. 4.—Adjustable pitot tube set.

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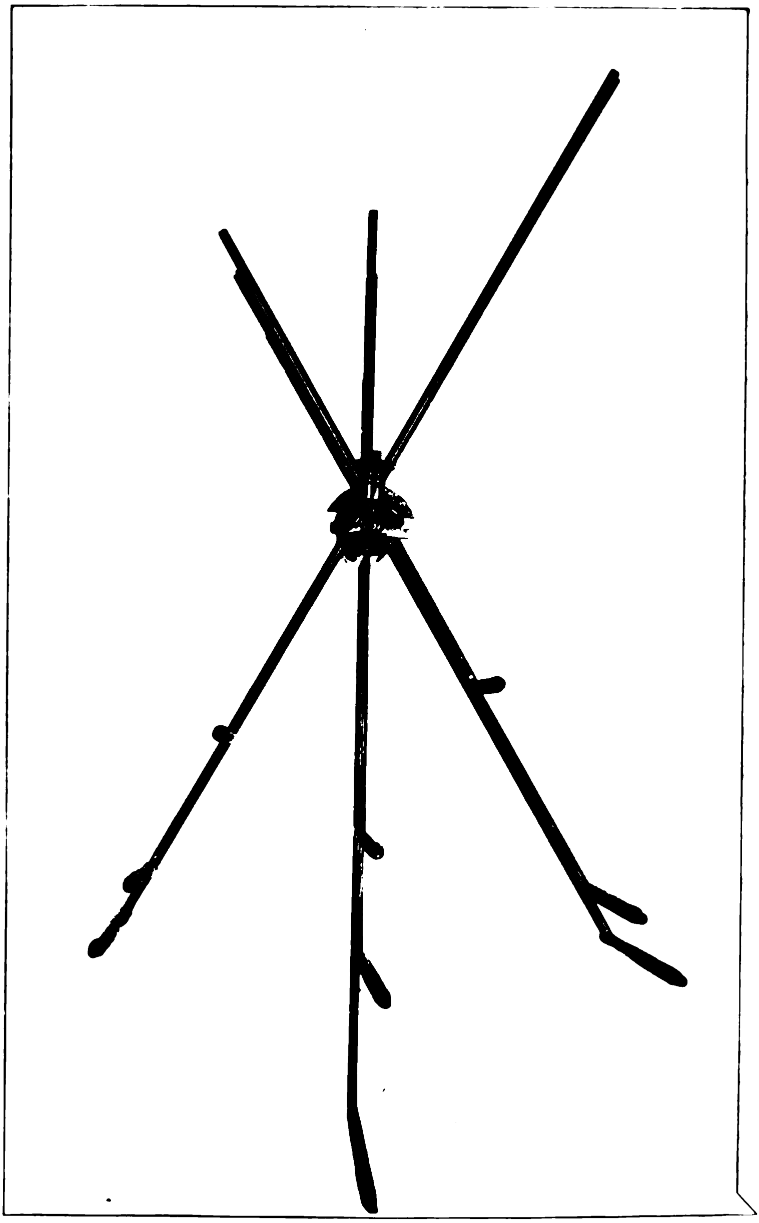

Fig. 5.—Adjustable pitot tube set.

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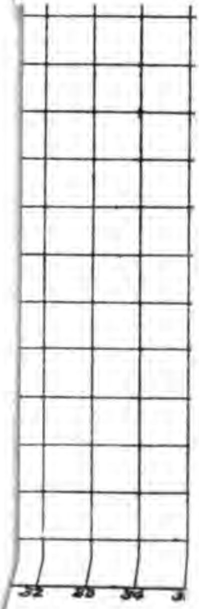
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33
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3

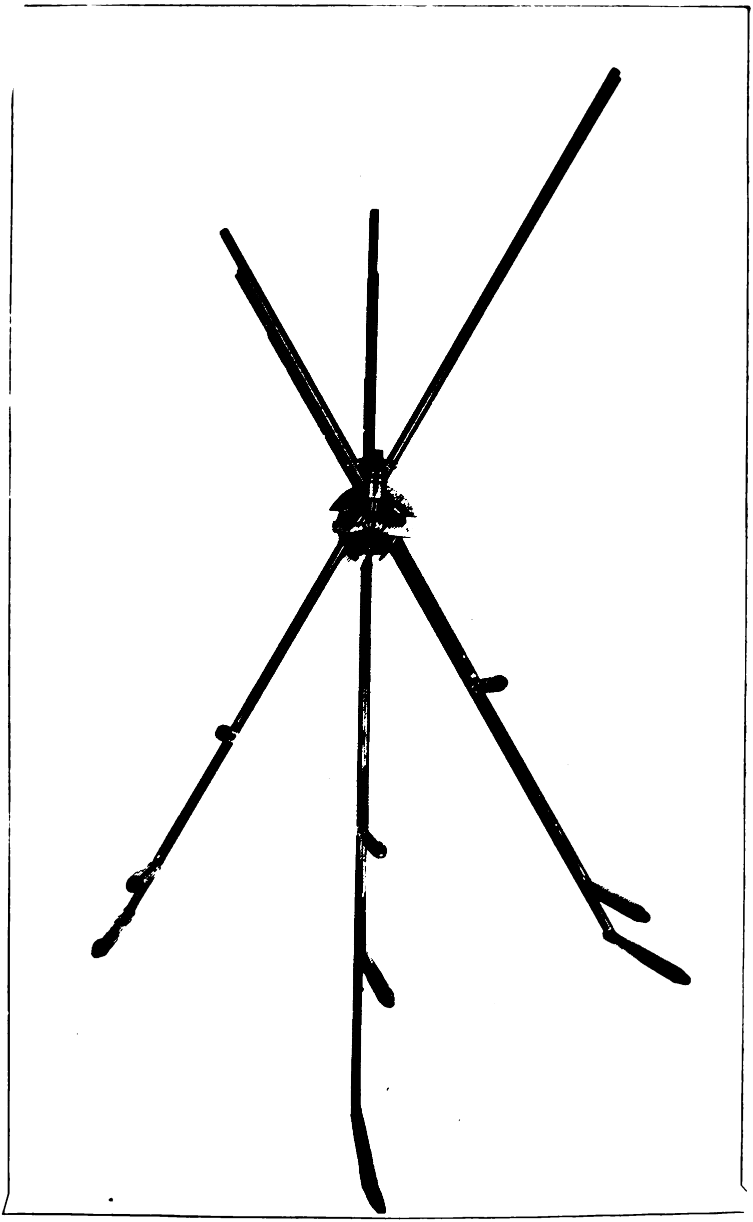

FIG. 5.—Adjustable pitot tube set.

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